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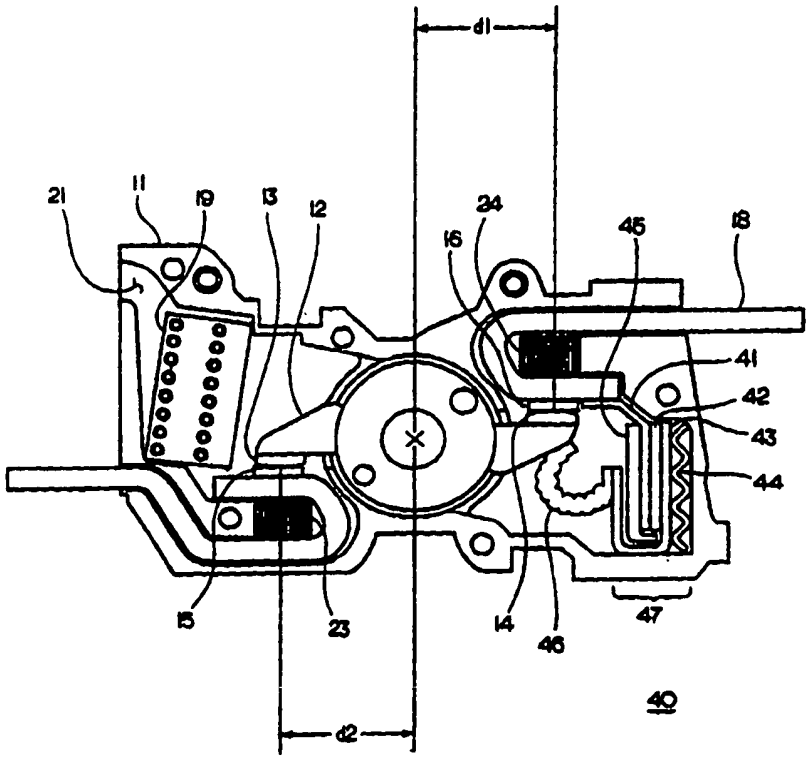
(54) Title: CURRENT LIMITING CIRCUIT BREAKER WITH CURRENT COMMUTATION

(57) Abstract

A compact current limiting circuit breaker utilizing two pairs of series connected contacts is equipped with a current limiter arranged in parallel with the second pair of contacts for improved overcurrent protection. Upon the occurrence of contact separation an arc is drawn at the first pair of contacts, but not the second. The presence of the polymer current limiter in parallel with the second pair of contacts causes the overcurrent to commutate into the polymer current limiter immediately upon separation of the second contacts. A means for enhancing the dielectric strength across the second pair of open contacts prevents an arc strike from shunting out the polymer current limiter during a high available short circuit.



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CURRENT LIMITING CIRCUIT BREAKER WITH CURRENT COMMUTATION

Background of the Invention

The use of arc chutes in compact electric circuit breakers for the purpose of arc extinction is well known in the field of circuit breaker engineering. The function of the arc chute is to attract an electrical arc that is drawn between the movable and stationary contacts as the contacts open in response to an overcurrent condition. The magnetic influence of the arc chute attracts the arc, which is then broken up into smaller arclets between the multiple plates within the arc chute. Each arclet has associated with it an anode-cathode fall, defined herein as the voltage appearing across each pair of arc plates within the arc chute, which when taken collectively produces sufficient electrical potential to exceed the system voltage and drive the current to zero, thereby effectively extinguishing the overcurrent. Such an arc chute is described in U.S. Patent No. 4,963,849 entitled "Compact Current Limiting Circuit Breaker". During this interruption process, the intense heat of the ionized plasma arc vaporizes edges and surfaces of the arc plates, produces high internal gas pressures and causes ionized particles to be exhausted from the circuit breaker into the circuit breaker enclosure. In order to prevent an electrical strike to grounded metal during an interruption process, the performance of the circuit breaker must be coordinated with the physical constraints of the circuit breaker enclosure.

U.S. Patent Application Serial No. 08/797,151 entitled "Current Suppressing Circuit Breaker Unit for Inductive Motor Protection" filed 10 February 1997 describes a current suppressing unit connected in series with a pair of circuit breaker contacts. During a short circuit overcurrent condition, the current suppressing unit rapidly suppresses the short circuit let-through current which is then extinguished by the opening of the circuit breaker contacts. The current suppressing unit utilizes a current limiting element that operates in a manner described in U.S. Patent No. 5,614,881 entitled "Current Limiting Device" which rapidly introduces high resistance to effectively limit the peak let-through current. The highly resistive current limiting element, in its switched state, rapidly suppresses the let-through current to a low residual value, which is then extinguished by the opening of the series connected circuit breaker contacts. The resulting arc of the residual current is driven into an arc chute where it is extinguished in accordance with the aforementioned U.S. Patent 4,963,849.

Italian Patent Application No. MI97A 001564 filed on 2 July 1997 and US Patent Application Serial No. 09/108,684 filed on 1 July 1998, both entitled "Rotary Contact Assembly for High Ampere-Rated Circuit Breakers", describe a rotary contact arm assembly that includes a contact arm with two movable contacts, one at each end, and a central pivot. The movable contacts are electrically connected in series when the contact arm assembly is in the CLOSED position. Each movable contact abuts a stationary contact. Articulation of the contact arm assembly causes both movable contacts to open simultaneously, thereby introducing two electrical arcs in series. The advantage of two electrical arcs in series, as opposed to only one, is a two-fold increase in the rate of rise of arc voltage, which rapidly suppresses a short circuit overcurrent.

U.S. Patent Application Serial No. 08/797,152 entitled "Circuit Breaker Current Limiting Arc Runner" filed 10 February 1997 describes a current limiting arc runner comprising a polymer current limiter that rapidly suppresses a short circuit overcurrent. The proximity of the current limiting arc runner to the movable contact arm promotes commutation of the arc current to the arc runner during contact separation.

U.S. Patent No. 5,424,503 entitled "Puffer Type Circuit Interrupter With Improved Blast Valve And Permanent Contact" describes a puffer type circuit interrupter which utilizes pressurized insulative gas to effectuate arc interruption. U.S. Patent No. 3,632,926 entitled "Current Limiting Circuit Breaker Having Arc Extinguishing Means Which Includes Improved Arc Initiation And Extinguishing Chamber Construction" describes the use of ablative material in the vicinity of the stationary contacts to effectuate arc interruption. Both systems require the introduction of specialized material specifically designed to introduce insulative gas into the arc interruption chamber.

U.S. Patent No. 4,677,266 entitled "Switch Device Having An Insulating Screen Inserted Between The Contacts During Breaking" describes a contact gap shutter arrangement which is effectively driven to bifurcate the contact gap by the increased gas pressure generated by the arc drawn between the contacts. Operation of this type of system is dependent on the existence of an arc drawn between the contacts. U.S. Patent No. 4,752,660 entitled "Current Limiting Circuit Breaker With An Arc Shearing Plate" describes a contact gap shutter arrangement which is effectively driven to bifurcate the contact gap by the same overcurrent responsive actuating member which initiates contact separation. Operation of this type of system is dependent on the overcurrent responsive actuating member working in concert with the opening action of the separable contacts.

One purpose of the instant invention is to provide an efficient short circuit interruption system that utilizes a polymer current limiter, as described in the aforementioned U.S. Patent 5,614,881, in parallel with a second pair of contacts of a two-contact rotary contact assembly, as described in the aforementioned Italian Patent Application No. MI97A 001564 and US Patent Application Serial No. 09/108,684 , and in concert with a means for enhancing the dielectric strength across the pair of open contacts in parallel with the polymer current limiter to prevent an arc strike from shunting out the polymer current limiter.

Summary of the Invention

A compact current limiting circuit breaker utilizes a polymer current limiter and a rotary contact assembly for effective overcurrent protection. Upon the occurrence of contact separation, the overcurrent is commutated from a second pair of contacts to a polymer current limiter, and an arc is drawn between a first pair of contacts and driven toward an arc chute. Commutation of the overcurrent into the polymer current limiter effectuates rapid suppression of the overcurrent. The polymer current limiter comprises a conductive polymer with abutting electrodes and higher resistance electrode interfaces.

Brief Description of the Drawings

Figure 1 is a side view of a Prior Art compact current limiting rotary circuit breaker with the cover removed to depict the circuit breaker operating components in the ON condition; and

Figure 2 is a side view of a compact current limiting rotary circuit breaker equipped with a polymer current limiter in accordance with the invention.

Figure 3 is a side view of a compact current limiting rotary circuit breaker equipped with a polymer current limiter and arc gas puffer in accordance with the invention.

Figure 4 is a partial side view of the circuit breaker housing of Figure 3 with detail removed for clarity.

Figure 5 is a partial section view of the circuit breaker housing of Figure 4 cut through Section A-A except with both halves of the circuit breaker housing shown.

Figure 6 is a partial side view of a compact current limiting rotary circuit breaker equipped with a polymer current limiter and contact gap shutter with detail removed for clarity in accordance with the invention.

Description of Preferred Embodiment

Figure 1 depicts a molded case circuit breaker 10 that operates in accordance with the teachings contained within aforementioned Italian Patent Application No. MI97A 001564 and US Patent Application Serial No. 09/108,684. A housing 11 supports an operating mechanism (not shown) that operates in a manner described in aforementioned Italian Patent Application No. MI97A 001564 and US Patent Application Serial No. 09/108,684 to articulate the contact arm 12 between an open and closed position for isolation of a protected circuit. Movable contacts 13, 14 on contact arm 12 abut stationary contacts 15, 16 on line strap 17 and load strap 18. Under quiescent operating conditions, the electrical current passes through the line strap 17, stationary contact 15, movable contact 13, contact arm 12, movable contact 14, stationary contact 16, and load strap 18. The line strap 17 provides an electrical connection between the external power source and the circuit breaker internal components. A load terminal (not shown) provides means to electrically connect the protected circuit to the load strap 18. Articulation of the contact arm 12 during a short circuit overcurrent condition is described in aforementioned Italian Patent Application No. MI97A 001564 and US Patent Application Serial No. 09/108,684. This action produces an electrical arc (not shown) that is directed towards arc chutes 19, 20, with eventual extinguishing through exhaust ports 21, 22. The contact arm 12 opening speed is enhanced by means of slot motors 23, 24.

First Embodiment with Polymer Current Limiter

A compact current limiting circuit breaker 40 is shown in Figure 2, wherein like reference numerals with respect to Figure 1 designate corresponding parts. Load strap 18 connects to a first electrode 41 which abuts one side of polymeric conductor 42 and is captivated by retainer 45 that is integral with housing 11. The other side of polymeric conductor 42 is biased against a second electrode 43 by means of a spring 44 which is captivated within housing 11. Second electrode 43 is electrically connected to contact arm 12 by means of braid 46. Opening of the contact arm 12 produces an electrical arc between movable contact 13 and stationary contact 15 that is magnetically driven towards arc chute 19, and also commutates the overcurrent from movable contact 14 and stationary contact 16 into the current path containing first electrode 41, polymeric conductor 42, second electrode 43, and braid 46. The commutated current is rapidly suppressed by the action of the polymer current limiter which operates in a manner described in the aforementioned U.S. Patent Application Serial No. 08/797,152. The residual suppressed current is eventually

extinguished by arc chute 19 with a reduced effluent being exhausted through exhaust port 21. The contact arm 12 opening speed is enhanced by means of slot motors 23, 24.

Dimensions d1 and d2 in Figure 2 can be set according to the application requirements. For a given rotational angle of contact arm 12 in the OPEN position, a condition where d1 > d2 provides for a greater voltage drop in the polymer current limiter 47, typically required for high level short circuit overcurrent, a condition where d1 < d2 provides for a greater voltage drop in the arc chute 19, typically required for low level short circuit overcurrent, and a condition where d1 = d2 provides symmetry for ease of manufacturing.

Second Embodiment with Polymer Current Limiter and Arc Gas Puffer

The compact current limiting circuit breaker 40 of Figure 2 is reproduced in Figure 3 with the addition of arc gas puffer 48, wherein similar parts correspond to like parts except with reference numerals omitted for clarity. Details of the arc gas puffer 48 are best seen by viewing Figures 3, 4 and 5 together. Gas duct 49, formed by the exterior structure of housing 11 and barrier 59, connects a first orifice 50, also designated as 50a-50h in Figure 4, with a second orifice 51 enabling the transport of pressurized gas from region 60, containing the polymer current limiter 47, comprising first electrode 41, polymeric conductor 42, second electrode 43, and compressive means such as spring 44 and retainer 45, to a region behind movable contact 14 and stationary contact 16 when the polymer current limiter 47 undergoes switching as described in aforementioned U.S. Patent Application Serial No. 08/797,152. Essentially, switching of the polymer current limiter 47 occurs during a short circuit overcurrent condition whereby the opening of contact arm 12 commutates the overcurrent into polymer current limiter 47 which results in resistive heating at the interface of polymeric conductor 42 and either first electrode 41 or second electrode 43 or both, which causes rapid thermal expansion and vaporization of the polymeric conductor 42. This surface ablative phenomena introduces a step change in circuit resistance due to the resistive nature of the now gaseous polymeric binder, and is referred to as switching, i.e. switching from low resistance to high resistance, and is distinctly different from positive temperature coefficient of resistance (PTCR) resistors which employ bulk resistive heating to effect a bulk material change to produce a bulk resistance change. The vaporization of the polymeric conductor 42 causes region 60 to become pressurized. Gas flow then proceeds from a region of relatively high pressure in region 60 in the vicinity of first orifice 50 to a region of relatively low pressure in the vicinity of second orifice 51. The velocity of the gas flow exiting second

orifice 51 is enhanced by the reduction of the gas flow cross-sectional area from first orifice 50 to second orifice 51. During this event, contact arm 12 has at least partially rotated to produce a contact gap between movable contact 14 and stationary contact 16. The pressurized gas which is expelled from second orifice 51 expands into the region between movable contact 14 and stationary contact 16 to effectively enhance the dielectric strength of the contact gap and further the rapid suppression of the overcurrent by the action of the polymer current limiter as described above. The increase in local pressure between the contact gap, or removal of contaminants from within the contact gap, or the cooling effect of the high velocity gas within the contact gap, or any combination thereof, all serve to increase the dielectric strength of the contact gap. The enhanced dielectric strength across the contact gap enables the polymer current limiter to sustain greater voltages without an arc strike developing across the contact gap thereby preventing a dramatic surge of excess overcurrent that could damage downstream devices in the protected circuit. The residual suppressed current is likewise extinguished in the manner described above by the action of the open circuit contact gap between stationary contact 15 and movable contact 13, and arc chute 19.

Third Embodiment with Polymer Current Limiter and Contact Gap Shutter

The compact current limiting circuit breaker 40 of Figure 2 is partially reproduced in Figure 6 with the addition of contact gap shutter 53 and guide 54, with detail omitted for clarity. Similar parts between Figures 2 and 6 correspond to like parts except with reference numerals omitted for clarity. Shutter 53 has a first end, or isolation barrier, 53a which cooperates with guide 54 formed in housing 11, a second end 53b which has a leg 53d adjacent contact arm 12, and an anchor 53c which is pivotally coupled to contact arm 12. Guide 54 has a first surface 55 which forms a pocket 57 extending in and out of the plane of the paper and on either side of stationary contact 16, in which stationary contact 16 is positioned, and a second surface 56 which forms an opening 58 extending in and out of the plane of the paper and on either side of stationary contact 16, through which movable contact 14 traverses during opening or closing of contact arm 12. The anchor 53c of shutter 53 is positioned on contact arm 12 to effectively promote translation of shutter 53 within guide 54 during opening or closing of contact arm 12. During an overcurrent condition where contact arm 12 opens in a manner as described above, clockwise rotation of contact arm 12 about the center of pivot 52 produces an angular displacement of anchor 53c with a substantial horizontal component. Thus, as contact arm 12 opens to produce a contact gap, so shutter 53

translates within guide 54 to bifurcate the developing contact gap. First and second surfaces 55, 56 of guide 54 cooperate with first end 53a of shutter 53 to confine the translational motion of shutter 53 within guide 54. Effective bifurcation of the contact gap between movable contact 14 and stationary contact 16 occurs when first end 53a of shutter 53 has translated sufficiently to completely cover both pocket 57 in first surface 55 and opening 58 in second surface 56. The width and length dimensions of first end 53a of shutter 53 is sized appropriately to ensure complete coverage of both pocket 57 and opening 58 when contact arm 12 is fully open, thereby enhancing the dielectric strength of the contact gap and furthering the rapid suppression of the overcurrent by the action of the polymer current limiter as described above. Placement of the isolation barrier between movable contact 14 and stationary contact 16 serves to increase the path length an arc would have to travel in order to short out the polymer current limiter, thereby effectively increasing the dielectric strength of the contact gap. The residual suppressed current is likewise extinguished in the manner described above by the action of the open circuit contact gap between stationary contact 15 and movable contact 13, and arc chute 19 (Figure 2).

CLAIMS

1. A compact current limiting circuit breaker comprising:

a circuit breaker housing;

a first pair of fixed contacts, one of said first fixed contacts being connected with a load strap at one end of said circuit breaker housing for connection with a protected electrical distribution circuit and another of said first fixed contacts being connected with a line strap at an opposite end of said circuit breaker housing for connection with said protected circuit;

a rotor pivotally arranged intermediate said pair of fixed contacts and supporting a movable contact arm;

a first pair of movable contacts, one of said first movable contacts being arranged at each end of said contact arm for moving in and out of abutment with said first fixed contacts to make and break electrical connection with said protected circuit;

an operating mechanism within said circuit breaker housing proximate said rotor, said operating mechanism being arranged for rotating said rotor and said movable contact arm and separating said first movable contacts from said first fixed contacts to break electrical connection with said protected circuit upon occurrence of an overcurrent in said protected circuit; and

a polymer current limiter electrically connected in parallel with said load strap and said contact arm for commutating said overcurrent into said polymer current limiter upon separation of said first fixed and said first movable contacts for rapid suppression of said overcurrent.

2. The compact current limiting circuit breaker of claim 1 including means for fastening said polymer current limiter to said circuit breaker housing.

3. The compact current limiting circuit breaker of claim 1 wherein said polymer current limiter comprises a first and second electrode arranged on opposite sides of a polymeric conductor.

4. The compact current limiting circuit breaker of claim 3 wherein said polymeric conductor comprises a polymeric binder with a vaporization temperature at which significant

gas evolution occurs below 800^0C and an electrically conductive filler within said polymeric binder.

5. The compact current limiting circuit breaker of claim 4 further including an interface proximate said polymeric conductor, said interface having a higher resistivity than said polymeric conductor whereby resistive heating of said interface causes rapid thermal expansion and vaporization of said polymeric conductor causing at least partial separation of at least one of said first and second electrodes from said polymeric conductor at said interface.

6. The compact current limiting circuit breaker of claim 5 including means for exerting compressive pressure on said polymeric conductor for effecting current commutation into said polymer current limiter under said overcurrent condition.

7. The compact current limiting circuit breaker of claim 3 wherein said polymeric conductor does not depend on a PTCR effect.

8. The compact current limiting circuit breaker of claim 3 where said first electrode is electrically connected to said load strap.

9. The compact current limiting circuit breaker of claim 3 where said second electrode is electrically connected to said contact arm.

10. The compact current limiting circuit breaker of claim 3 where said second electrode is electrically connected to said contact arm by a flexible conductor.

11. The compact current limiting circuit breaker of claim 6 where said compressive means comprises a spring.

12. The compact current limiting circuit breaker of claim 2 where said fastening means comprises an interference fit within said circuit breaker housing.

13. The compact current limiting circuit breaker of claim 1 where said movable contact arm defines first and second dimensions d1 and d2 characterizing a distance from a rotational axis of said contact arm to said movable contacts arranged at each end of said contact arm, respectively.

14. The compact current limiting circuit breaker of claim 13 where d1 is substantially equal to d2.

15. The compact current limiting circuit breaker of claim 13 where d1 is sufficiently greater than d2 to permit a greater voltage drop to develop across said polymer current limiter as opposed to across said second fixed and said second movable contacts for enhanced current limiting in said current limiter during said overcurrent condition.

16. The compact current limiting circuit breaker of claim 13 where d1 is sufficiently less than d2 to permit a greater voltage drop to develop across said second fixed and said second movable contacts as opposed to across said polymer current limiter for enhanced arc voltage generation across the contact gap of said second fixed and said second movable contacts during said overcurrent condition.

17. The compact current limiting circuit breaker of claim 1 further comprising a arc gas puffer proximate said first fixed and said first movable contacts for promoting gas flow between said first fixed and said first movable contacts during switching of said polymer current limiter for enhanced contact gap dielectric strength.

18. The compact current limiting circuit breaker of claim 17 wherein said arc gas puffer comprises at least one gas duct with at least one first orifice proximate said polymer current limiter and at least one second orifice proximate said first fixed contact for directing gas flow from said at least one first orifice to said at least one second orifice.

19. The compact current limiting circuit breaker of claim 18 wherein said at least one second orifice is positioned between said first fixed contact and the pivot of said rotor to promote gas flow away from the pivot of said rotor for enhanced contact gap dielectric strength.

20. The compact current limiting circuit breaker of claim 18 wherein said at least one gas duct is arranged within said circuit breaker housing with a gas flow cross-sectional area which reduces in cross-sectional dimension from said at least one first orifice to said at least one second orifice for promoting increased gas velocity at the exit of said at least one second orifice.

21. The compact current limiting circuit breaker of claim 1 further comprising a contact gap shutter arranged between said first fixed and said first movable contacts upon separation of said first fixed and said first movable contacts for enhanced contact gap dielectric strength.

22. The compact current limiting circuit breaker of claim 21 wherein said contact gap shutter comprises an isolation barrier having a first end proximate said first fixed contact and a second end anchored to said contact arm, and directed by a guide within said circuit breaker housing.

23. The compact current limiting circuit breaker of claim 22 wherein said guide comprises a first surface and a second surface, said first surface forming a recessed pocket for positioning of said first fixed contact, and said second surface forming an opening for passage of said first movable contact.

24. The compact current limiting circuit breaker of claim 23 wherein said isolation barrier is larger than said recessed pocket and said opening for effectively closing off said recessed pocket and said opening upon separation of said first fixed and said first movable contacts.

25. The compact current limiting circuit breaker of claim 22 wherein said anchor is effectively positioned on said contact arm to promote translation of said isolation barrier between said first fixed and said first movable contacts upon separation of said first fixed and said first movable contacts.

26. The compact current limiting circuit breaker of claim 22 wherein said second end of said isolation barrier comprises at least one leg adjacent said contact arm and pivotally coupled to said contact arm.

27. The compact current limiting circuit breaker of claim 22 wherein said isolation barrier is comprised of insulation material.

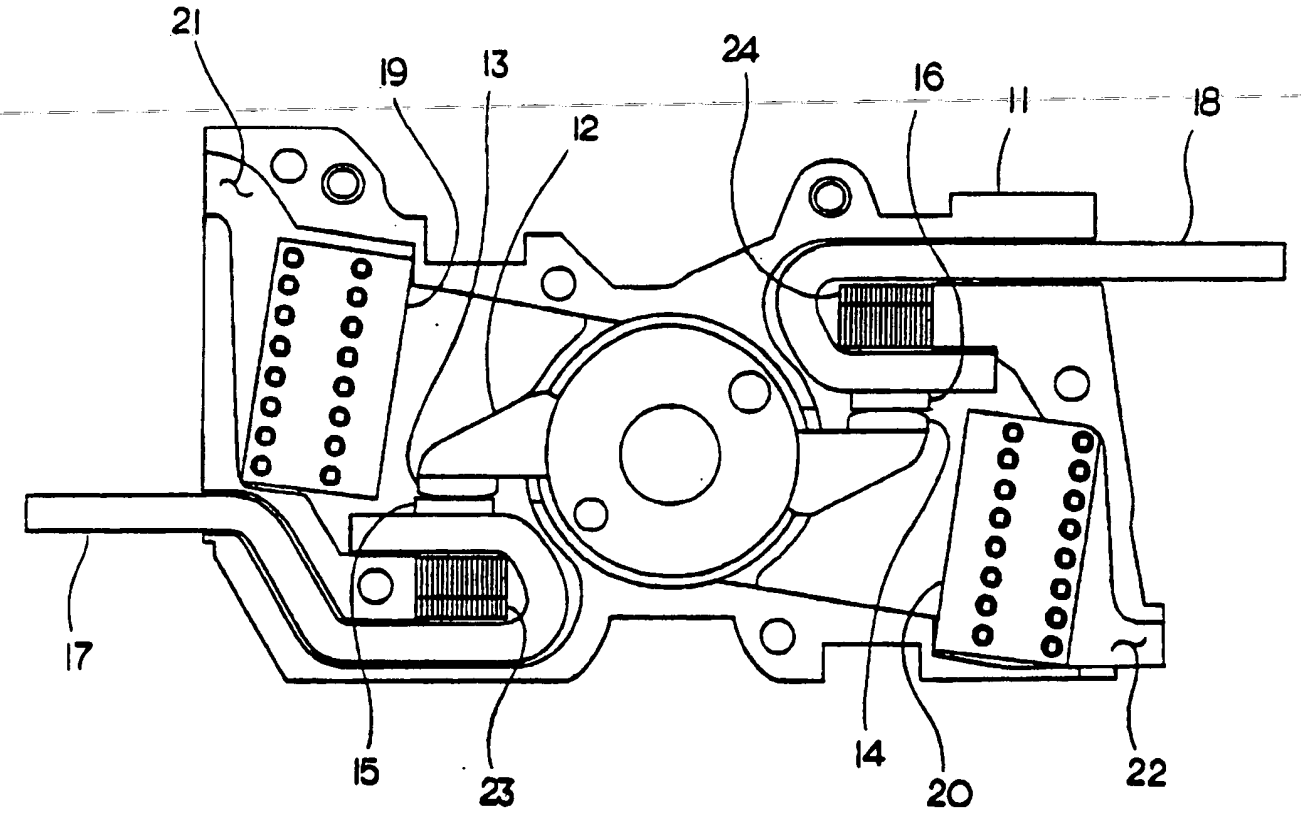

FIG. 1

(PRIOR ART)

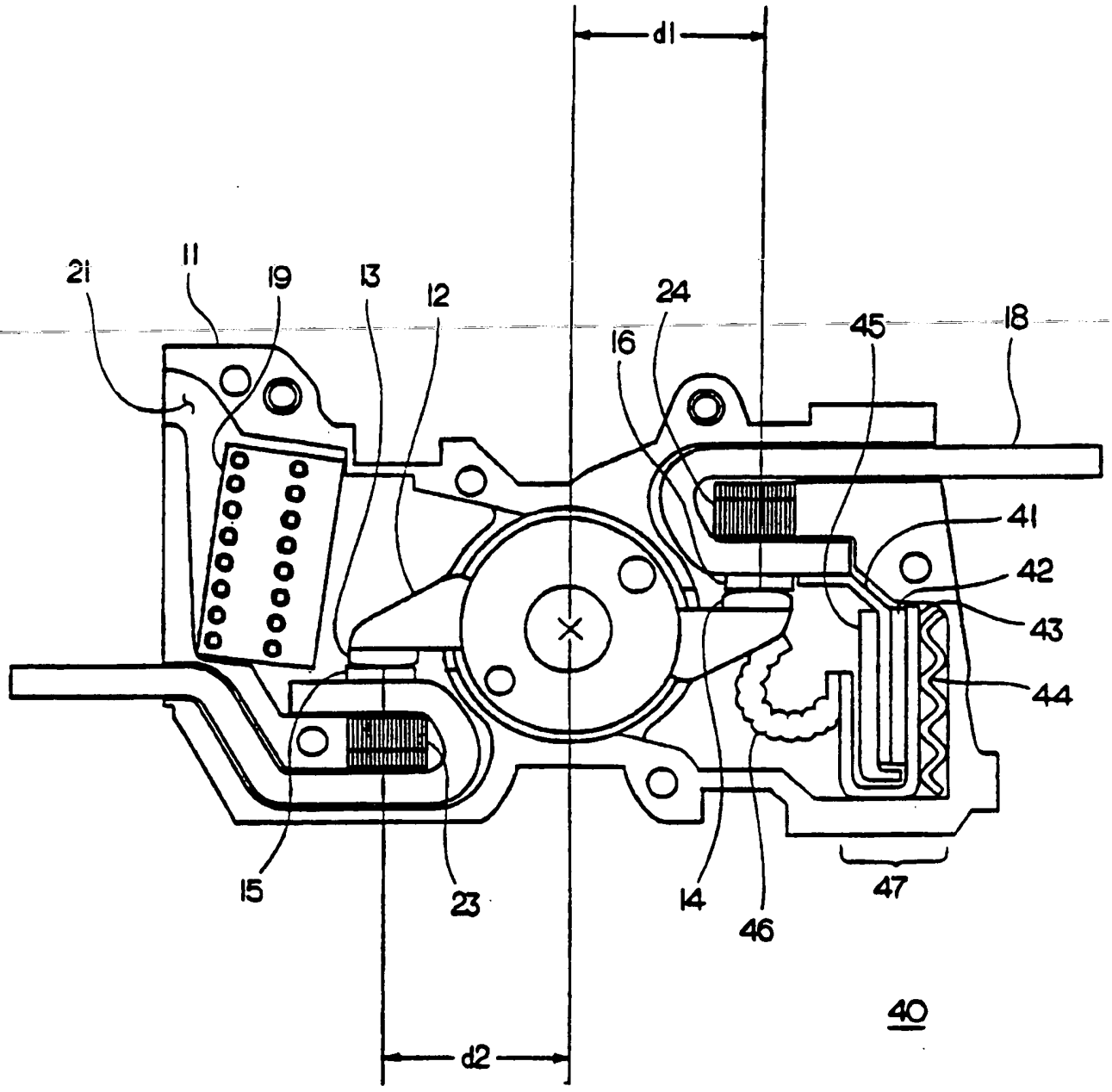

FIG. 2

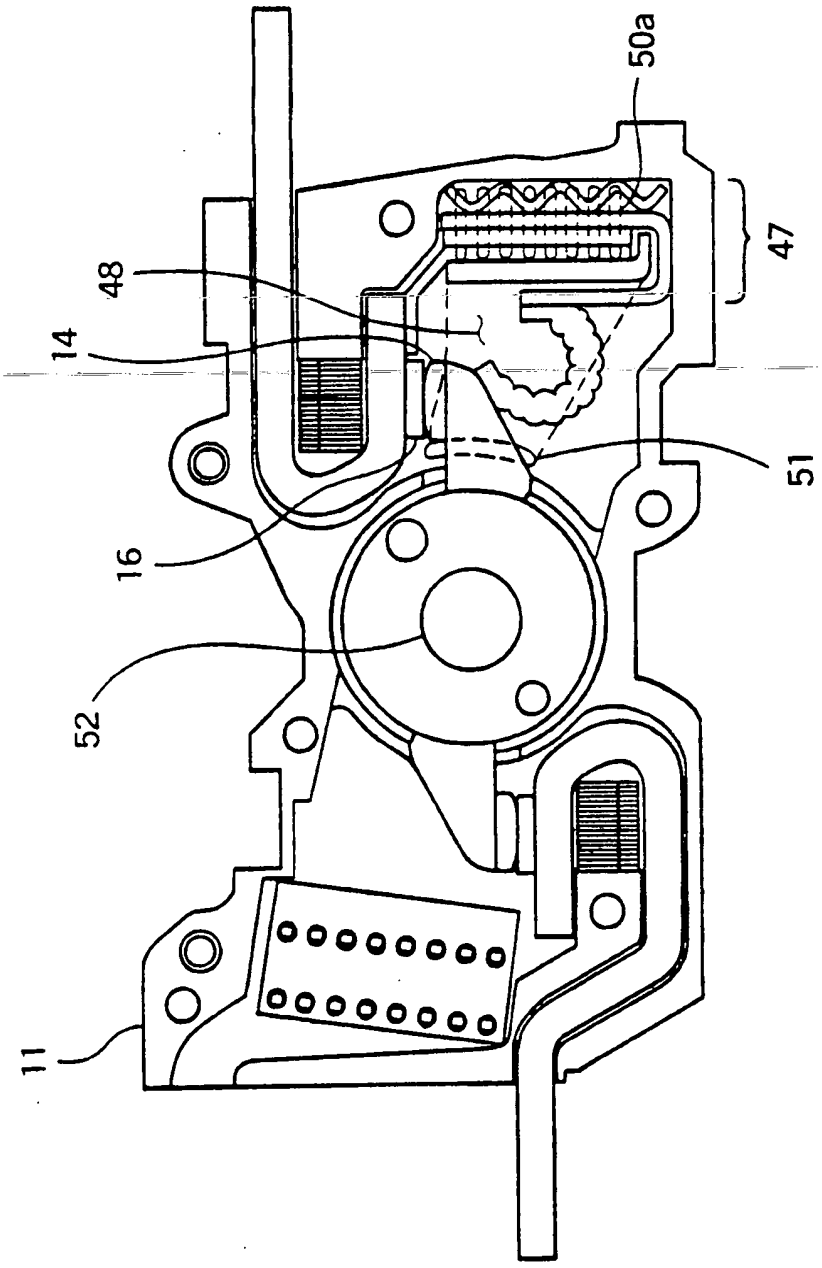

FIG. 3

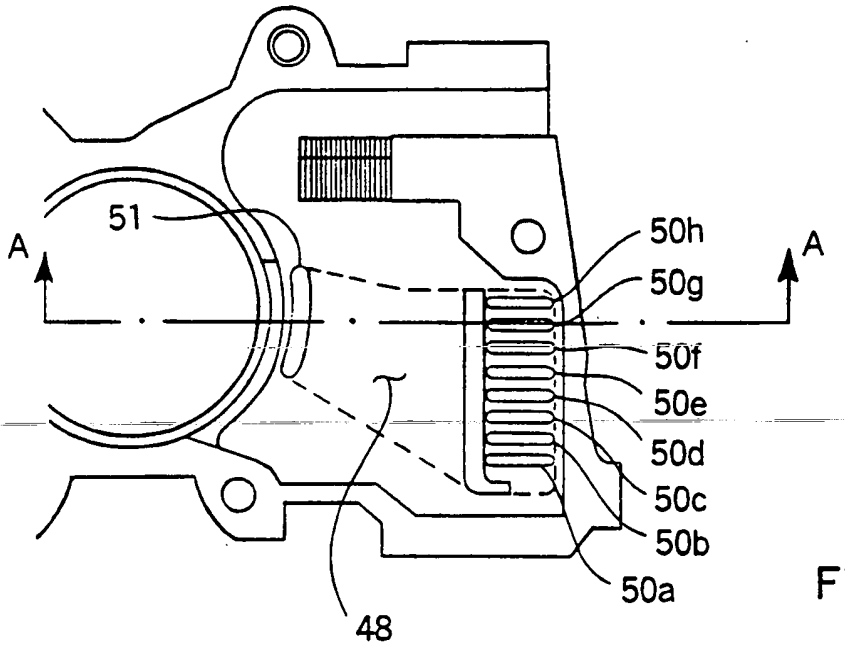

FIG. 4

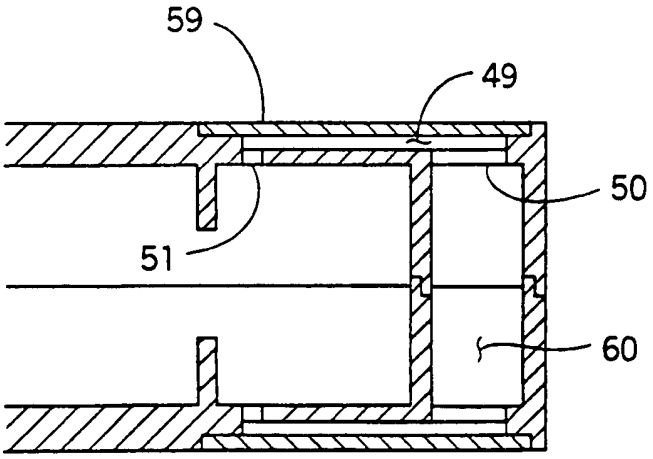

FIG. 5

Section A-A

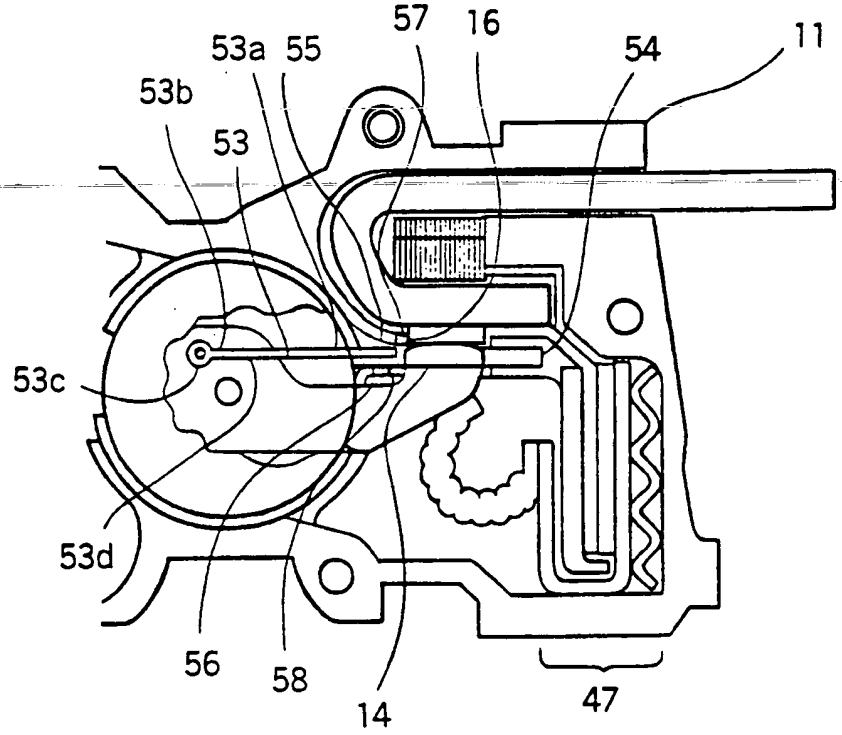

FIG. 6

INTERNATIONAL SEARCH REPORT

In ational Application No
PCT/US 98/19705

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01H9/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 212 661 A (ASEA AB) 4 March 1987 see page 6, last paragraph - page 7; figures 7,8	1
Y	US 5 614 881 A (DUGGAL ANIL R ET AL) 25 March 1997 cited in the application see abstract; figure 1	1
A	US 5 313 180 A (VIAL DENIS ET AL) 17 May 1994 see abstract; figures	1
A	US 4 213 022 A (EMMERICH WERNER S) 15 July 1980	
A	US 5 477 016 A (NEBON JEAN-PIERRE ET AL) 19 December 1995	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	12/01/1999

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Ir ational Application No
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